1971
USDA FOREST SERVICE RESEARCH PAPER PNW-124

Partial Cutting of Western Hemlock and Sitka Spruce in Southeast Alaska

WILBUR A. FARR
A.S. HARRIS

PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION
U.S. Department of Agriculture
Forest Service

ABSTRACT

This study of response to partial cutting over a 17-year period in a 96-year-old stand of western hemlock-Sitka spruce at Karta Bay, Alaska, showed that crop trees left after partial cutting were able to increase or maintain about the same rate of diameter growth as before thinning, but growth in diameter of trees in an unthinned stand followed the normal pattern of decline.

Opening the stand stimulated epicormic branching, thus reducing quality of trees in the future. Partially cut plots became well stocked with conifer regeneration, mostly western hemlock.

Keywords: Thinning, rotation age, western hemlock, *Tsuga heterophylla*, Sitka spruce, *Picea sitchensis*.

CONTENTS

INTRODUCTION

In the Pacific Northwest and Alaska, clearcutting is the harvesting method generally used with even-aged management of western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) and Sitka spruce (*Picea sitchensis* (Bong.) Carr.). But there may be situations where the forest manager would want to harvest a rotation-aged stand by some method other than clearcutting. Examples would be in areas where esthetic considerations limit clearcutting or where selected crop trees are to be retained in the stand for production of high-quality saw logs. Studies made elsewhere (Staebler 1957, Griffith 1959, Williamson 1966, Malmberg[1/]) show that young western hemlock and Sitka spruce respond well to thinning, and that these species have great potential for producing stands with high volumes of wood over a rotation.

In southeast Alaska, even-aged stands of western hemlock and Sitka spruce are typically dense. At an age of about 100 years, these stands contain some 12,000 cubic feet of wood per acre in trees averaging 12 inches in diameter at breast height. Diameters of largest trees are 20-25 inches, and there are few quality saw logs (Taylor 1934). In 1950, a study was begun to investigate the effect of partial cutting in such stands. One objective, as reported earlier (Godman 1951), was to determine the volume that could be removed and the time required to remove it. Selected crop trees were left for future sawtimber harvest. A second objective, herein described, was to evaluate the effects of partial cutting on stand growth, epicormic branching, and regeneration establishment.

The study originally had two replications of three treatments. Unfortunately, one of the replications had to be abandoned in 1962 when an adjacent blowdown changed conditions of light on the plots. Because one set of plots was lost, no statistical comparisons could be made between treatments. What is presented here is a case study of six small populations, and no inferences can be made beyond these plots with any stated probability. Analysis of these plots does provide some insight into the probable effects of partial cutting on stand growth, epicormic branching, and regeneration establishment.

METHODS

In the summer of 1950, three 1/2-acre plots were established in a 96-year-old stand of western hemlock and Sitka spruce at each of two locations at Karta Bay (fig. 1). The plots were on a Karta-Wadleigh soil complex (Gass et al. 1967). At each location one plot was thinned to 120 crop trees per acre, one was thinned to about two-thirds of the original basal area, and one was left unthinned (table 1). Thinning was essentially from below, but all wolf trees and poorly formed trees were also cut. Volumes removed ranged from 1,930 to 4,420 cubic feet per acre, with an average of 2,880.

There were noticeable differences between plots (table 1). Area 1 plots had higher site indices, fewer trees, and larger average diameters of trees than plots in

---

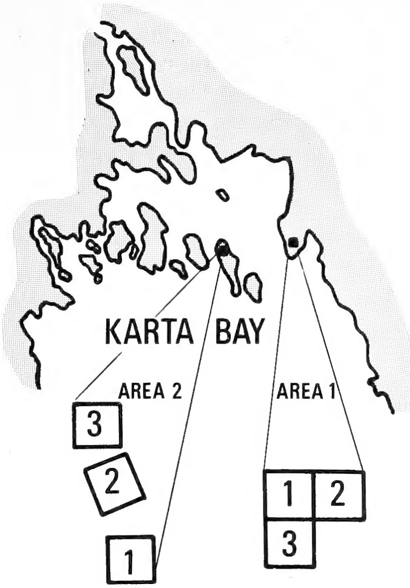
[1/] D. G. Malmberg. Early thinning trials in western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) related to stand structure and product development. Ph. D. dissertation on file at University of Washington, 138 p., illus., 1965.

Table 1.–*Plot statistics for 96-year-old western hemlock and Sitka spruce stand thinned in 1950, Karta Bay, Prince of Wales Island, Alaska*

(Per acre basis)

Area	Plot	Treatment	Site index	Before thinning			After thinning				Trees removed			
				Average d.b.h.	Trees	Basal area	Average d.b.h.	Trees	Basal area	Hemlock crop trees	Average d.b.h.	Trees	Basal area	Basal area cut
				Inches	*Number*	*Sq. ft.*	*Inches*	*Number*	*Sq. ft.*	*Percent*	*Inches*	*Number*	*Sq. ft.*	*Percent*
1	1	120 crop trees	130	16.3	236	341	18.5	120	224	70	13.6	116	117	34.3
	2	Two-thirds of basal area	121	14.2	306	337	15.7	174	234	88	12.0	132	103	30.6
	3	Unthinned	121	15.7	262	351	15.7	262	351	84	0	0	0	0
2	1	120 crop trees	109	11.1	562	379	15.8	120	164	22	9.4	442	215	56.7
	2	Two-thirds of basal area	116	13.4	424	413	16.8	172	263	64	10.4	252	150	36.3
	3	Unthinned	113	13.0	378	346	13.0	378	346	53	0	0	0	0

Figure 1.--*Location of thinned plots at Karta Bay, Prince of Wales Island, Alaska.*



area 2. After thinning, 70 to 88 percent of the trees in area 1 were hemlock, whereas 22 to 64 percent in area 2 were hemlock. Thirty-one to 34 percent of the basal area was removed from area 1 plots and 36 to 57 percent from plots in area 2.

At the time of thinning, there were no markets for pulp timber, so the felled trees were limbed and bucked and left on the ground. A 1/10-acre subplot (66 feet square) at the center of each thinned plot was cleared of logs and slash so that growth of advanced and new regeneration would not be hampered (fig. 2). All trees on the thinned plots and selected crop trees on the unthinned plots were remeasured in 1956 and 1960. Total growth of all trees on the unthinned plots was not determined in 1956 or 1960. In 1962, the timber adjacent to the plots in area 1 (fig. 1) was blown down causing such a change in light conditions that those plots were abandoned.

Figure 2.--*One-half-acre plot thinned to two-thirds of basal area in 1950, as it appeared in 1967. A 1/10-acre subplot was cleared of logs and slash so that growth of advanced and new regeneration would not be hampered. Plot 2, area 2, Karta Bay, Prince of Wales Island, Alaska.*

In 1967, the three plots in area 2 were again remeasured and two increment cores were extracted at right angles to each other from all crop trees on plots 1 and 3. Cores were not taken from trees on plot 2 as this plot had been maintained as a permanent growth plot since 1928. The increment cores from plots 1 and 3 were used to obtain estimates of tree diameters during the period 1928-50 so that trends in growth before thinning could be determined. Height measurements were seldom taken in past years and no analysis was made of changes in tree form. Only diameter and basal-area growth were considered.

The first 33-foot section[2/] of each Sitka spruce crop tree in area 2 was inspected in 1967 to determine if thinning noticeably stimulated epicormic branching. The number of epicormic branches on each tree was tallied in two classes--branches of one-half inch or smaller and those of more than one-half inch in diameter.

To determine changes in regeneration after partial cutting, we divided the 1/10-acre cleared subplots into 100 1-milacre (6.6 feet square) plots. In the spring of 1951, the number and species of seedlings on each milacre plot were counted. Seventeen growing seasons later (1967), seedlings were again counted by species on each milacre plot and the height of the largest spruce and hemlock on each was measured.

An estimate of crown cover was made in 1967 from 25 vertical ground photos taken on each plot. Canopy cover was estimated from photos by superimposing a 50-dot grid on the photos and recording the percentage of dots falling on foliage, boles, and branches.

RESULTS

Diameter Growth

Before thinning, rate of growth of crop trees on the three plots in area 2 were similar (table 2). Over the first 10 growing seasons following thinning, 1951-60, crop trees on thinned plots showed greater growth than similar crop trees on the unthinned plots. Differences in growth between trees on thinned and unthinned plots were even more striking during the period 1961-67 (table 2). Hemlock and spruce showed similar response to treatment.

Trees on the plot thinned to 120 trees per acre increased their average rate of diameter growth for the first 10 growing seasons following thinning. Diameter growth during the next seven growing seasons decreased somewhat but remained above the pre-thinning level.

Trees on the plot thinned to two-thirds of basal area maintained their rate of diameter growth at about the 1928-50 level for the first 10 years following thinning. During the next 7 years, diameter growth of these trees decreased to below the pre-thinning level. Growth of similar trees on the unthinned plot has declined since 1950 (table 2).

[2/] Includes a 1-foot stump and first 32-foot log.

Table 2.–*Average diameter and diameter growth on thinned and unthinned plots at Karta Bay, Prince of Wales Island, Alaska*

Treatment	Plot	Area	Average diameter of crop trees at end of growing season				Average annual diameter growth of crop trees by period		
			1927	1950	1960	1967	1928-50	1951-60	1961-67
			Inches						
Thinned to 120 trees per acre	1	1	--	18.5	19.6	--	--	0.11	--
	1	2	13.7	15.8	17.0	17.7	0.09	.12	0.10
Unthinned (comparison of 120 crop trees per acre)[1/]	3	1	--	17.5	18.2	--	--	.07	--
	3	2	14.8	16.8	17.6	17.9	.09	.08	.04
Thinned to two-thirds of basal area	2	1	--	15.7	16.4	--	--	.07	--
	2	2	14.8	16.8	17.7	18.2	.09	.09	.07
Unthinned (comparison of two-thirds of basal area)[2/]	3	1	--	17.4	18.0	--	--	.06	--
	3	2	13.8	15.6	16.2	16.5	.08	.06	.04

1/ Includes only those trees on the control plots that would have been left had the plots been thinned to 120 trees per acre.

2/ Includes only those trees on the control plots that would have been left had the plots been thinned to two-thirds of the original basal area.

Basal Area Growth

Basal area growth on thinned plots was surprisingly good (table 3). Information gathered from the plots in area 2 shows that trees on the thinned plots more than doubled the net basal area increment of trees on the unthinned plot. This is principally due to the natural mortality of 27 trees on the unthinned plot between 1950 and 1967. There was no mortality among selected crop trees on the unthinned plot. The mortality took place in the smaller diameter classes where there was a net loss to basal area growth. Because of the loss in the smaller diameter classes, net growth for all trees on the plot was less than net growth on selected crop trees (table 3). Unfortunately, we do not know total basal area growth for trees on the unthinned plot in area 1.

In the 17 years, 1951-67, no trees died in area 2 on the plot thinned to two-thirds of basal area, and one tree died on the plot thinned to 120 crop trees per acre. Between 1951 and 1960 in area 1, two trees were windthrown on the plot thinned to 120 crop trees per acre, and one tree was windthrown on the plot thinned to two-thirds of basal area. Four of the selected crop trees on the unthinned plot died.

Epicormic Branching

Percent of spruce crop trees with epicormic branching in area 2 in 1967 was positively correlated with thinning intensity (table 4). The heavier the 1950 thinning, the greater the epicormic branching by 1967. In 1967, on the plot thinned to 120 crop trees per acre, 62 percent of the spruce had epicormic branches compared with 32 percent for the unthinned plot. The number of epicormic branches in the first 33-foot tree section of affected trees was similar on all plots.

Regeneration

Regeneration response after thinning was studied on the three plots in area 2. In 1951, the year after thinning, established seedlings were more numerous on the unthinned plot than on thinned plots (table 5), probably because many seedlings on the thinned plots were destroyed during thinning. All the seedlings present were hemlock. By 1967, however, fewer than half of the seedlings on the unthinned plot remained, but on both thinned plots, seedlings were 19 and 47 times more numerous than in 1951 (figs. 2 and 3). This change in relative number of seedlings from 1951 to 1967 was associated with conditions of light. In 1967, crown cover on the unthinned plot was 94 percent, but on the thinned plots, crown cover was 76 and 83 percent.

Reduction of crown cover on thinned plots improved conditions for spruce regeneration. By 1967, spruce accounted for 15 and 20 percent of the regeneration on thinned plots, but no spruce regeneration was observed on the unthinned plot. Hemlock seedlings were taller on the thinned plots than on the unthinned plot. The difference in average height of hemlock and spruce is due principally to difference in age of the two species; many of the hemlock were already established before thinning, but spruce became established only after the stands were thinned.

Table 3.–*Basal area growth and mortality on thinned and unthinned plots at Karta Bay, Prince of Wales Island, Alaska*

(Per acre basis)

Treatment	Plot	Area	Net growth				Mortality			Gross growth		
			1928-50	1951-60	1961-67	1951-67	1951-60	1961-67	1951-67	1951-60	1961-67	1951-67
			Square feet									
Thinned to 120 trees per acre	1	1	--	17.2	--	--	8.2	--	--	25.4	--	--
	1	2	39.9	22.1	15.4	37.5	2.4	0	2.4	24.5	15.4	39.9
Unthinned (comparison of 120 crop trees per acre)[1/]	3	1	--	6.0	--	--	8.9	--	--	14.9	--	--
	3	2	41.4	16.1	4.7	20.8	0	1.8	1.8	16.1	6.5	22.6
Thinned to two-thirds of basal area	2	1	--	18.6	--	--	1.2	--	--	19.8	--	--
	2	2	61.4	28.4	10.4	38.8	0	0	0	28.4	10.4	38.8
Unthinned (comparison of two-thirds of basal area)[2/]	3	1	--	3.8	--	--	12.9	--	--	16.7	--	--
	3	2	51.4	19.0	7.2	26.2	0	1.8	1.8	19.0	9.0	28.0
Unthinned (all live trees)	3	2	82.9	[3/] 13.2	3.5	16.7	--	--	--	--	--	--

1/ Includes only those trees on the control plots that would have been left had the plots been thinned to 120 crop trees per acre.

2/ Includes only those trees on the control plots that would have been left had the plots been thinned to two-thirds of basal area.

3/ Estimate based on straight line interpretation of excess tree basal area in 1949 and 1967, assuming constant basal area growth over the period.

Table 4.–*Size and number of epicormic branches in the first 33-foot section of Sitka spruce crop trees, area 2, Karta Bay, Prince of Wales Island, Alaska, 1967*

Plot	Treatment	Spruce on 1/2-acre plot	Epicormic branching of Sitka spruce: Spruce with epicormic branches	Branches by average size in first 33-foot tree section: ≤ 1/2 inch	> 1/2 inch
		Number	*Percent*	*Number*	*Number*
1	120 crop trees per acre	47	62	3.4	3.9
2	Two-thirds of basal area	31	42	3.8	5.0
3	Unthinned	42	32	4.1	4.5

Table 5.–*Regeneration condition on thinned and unthinned plots, Karta Bay, Prince of Wales Island, Alaska*

Timber stand description				Regeneration condition							
				1951			1967				
Plot number	Treatment	Basal area (1950)	Crown cover (1967)	Seedlings per acre	Species of seedlings		Seedlings per acre	Species of seedlings		Average height of dominant seedlings	
					Hemlock	Spruce		Hemlock	Spruce	Hemlock	Spruce
		Sq. ft.	*Percent*	*Number*	-----*Percent*-----		*Number*	------*Percent*------		-------*Feet*------	
1	120 trees per acre	164	76	480	100	0	22,650	80	20	4.7	1.2
2	Two-thirds of basal area	263	83	1,330	100	0	25,070	85	15	6.8	2.3
3	Unthinned	346	94	3,840	100	0	1,700	100	0	2.7	--

Figure 3.--*Half-acre control plot as it appeared in 1967. The ground was covered with a thick layer of duff and litter; hemlock and spruce regeneration was sparse. Plot 3, area 2, Karta Bay, Prince of Wales Island, Alaska.*

In 1967, both thinned plots supported a dense understory of tree seedlings, mostly western hemlock. Red huckleberry (*Vaccinium parvifolium* Smith), swordfern (*Polystichum munitum* (Kaulf.) Presl.), and other understory plants were present in small numbers on all plots. On both thinned plots, a deep carpet of feather mosses covered the ground except under dense thickets of seedlings. In contrast, on the unthinned plot, the ground was largely covered with about 8 inches of duff and litter. Moss was scarce, and the hemlock seedlings were spindly and lacked vigor. Most seedlings were located along the western edge of the plot where lighting from the more open adjacent stand was greatest.

DISCUSSION

Over the 17 years following cutting, these 96-year-old stands responded well to thinning. The partial cut apparently removed many trees that would have died during the 17-year period, plus many more that would have contributed little toward increasing stand volume. Crop trees on thinned plots, even at the advanced age of 96 years, were able to make some use of the additional growing space.

Growth of individual trees on the plot thinned to 120 trees per acre was stimulated by thinning, and trees on the plot thinned to two-thirds of basal area were able to maintain their diameter growth at about the prethinning level. Diameter growth on the unthinned plot followed the normal pattern of decline.

With sawtimber as the product objective, quality is important. Sitka spruce is a slow natural pruner, and as stands are opened, epicormic branching increases (Herman 1964). Production of quality wood would require artificial pruning in partially cut stands both to remove persistent branch stubs and to control epicormic branching. Even then it would take 4 to 12 years or more for production of clear wood over smooth branch cuts (Harris 1966).

The study was not designed to compare regeneration after partial cutting and clearcutting although, in considering the use of partial cutting as an alternative to

clearcutting, this question would certainly arise. We do not consider regeneration to be a problem on sites having Karta and Wadleigh soils and gentle topography. Based on reconnaissance in young stands that have developed after clearcutting, we would expect dominant trees to be 20 to 30 feet tall and 3 to 6 inches in diameter 18 years after clearcutting, with spruce comprising roughly 50 percent of the basal area. Thus, regeneration would probably be better had the stand been clearcut.

Blowdown on the study plots was not a serious problem. However, hemlock and spruce are shallow-rooted species, and many existing young-growth stands originated following blowdown of the previous stand. The treated plots at Karta Bay were damaged only slightly by wind during the 17-year study, and although plots in area 1 were abandoned after a blowdown of adjacent timber, this blowdown did not result from partial cutting. The plots at Karta Bay were only one-half acre in size and were well protected by the surrounding stand. How large tracts of partially cut timber might be affected by strong winds is unknown.

LITERATURE CITED

Gass, Charles R., Richard F. Billings, Freeman R. Stephens, and Mervin E. Stevens.
1967. Soil management report for the Hollis area. USDA Forest Serv., S. Tongass Nat. Forest, Alaska, 118 p., illus.

Godman, R. M.
1951. Thinning second-growth hemlock-spruce for pulpwood. USDA Forest Serv., Alaska Forest Res. Center Tech. Note 7, 1 p. Juneau.

Griffith, B. G.
1959. The effect of thinning on a young stand of western hemlock. Forest. Chron. 35(2): 114-133, illus.

Harris, A. S.
1966. A test of pruning Sitka spruce in Alaska. USDA Forest Serv. Res. Note NOR-13, 3 p., illus. Northern Forest Exp. Sta., Juneau.

Herman, Francis R.
1964. Epicormic branching of Sitka spruce. USDA Forest Serv. Res. Pap. PNW-18, 9 p., illus. Pac. Northwest Forest & Range Exp. Sta., Portland, Oreg.

Staebler, George R.
1957. Early effect of two successive thinnings in western hemlock. USDA Forest Serv. Pac. Northwest Forest & Range Exp. Sta. Res. Note 146, 8 p. Portland, Oreg.

Taylor, R. F.
1934. Yield of second-growth western hemlock-Sitka spruce stands in southeastern Alaska. U.S. Dep. Agr. Tech. Bull. 412, 30 p., illus.

Williamson, Richard L.
1966. Shelterwood harvesting: tool for the woods manager. Pulp & Pap. 40(1): 26-29.

GPO 985-181

Farr, Wilbur A., and A. S. Harris.
1971. Partial cutting of western hemlock and Sitka spruce in southeast Alaska. USDA Forest Serv. Res. Pap. PNW-124, 10 p., illus. Pacific Northwest Forest & Range Experiment Station, Portland, Oregon.

Crop trees left after partial cutting were able to increase or maintain about the same rate of diameter growth as before thinning, but growth in diameter of trees in an unthinned stand followed the normal pattern of decline.

Opening the stand stimulated epicormic branching, thus reducing quality of trees in the future. Partially cut plots became well stocked with conifer regeneration, mostly western hemlock.

Keywords: Thinning, rotation age, western hemlock, *Tsuga heterophylla*, Sitka spruce, *Picea sitchensis*.

Farr, Wilbur A., and A. S Harris
1971. Partial cutting of western hemlock and Sitka spruce in southeast Alaska. USDA Forest Serv. Res. Pap. PNW-124, 10 p., illus. Pacific Northwest Forest & Range Experiment Station, Portland, Oregon.

Crop trees left after partial cutting were able to increase or maintain about the same rate of diameter growth as before thinning, but growth in diameter of trees in an unthinned stand followed the normal pattern of decline.

Opening the stand stimulated epicormic branching, thus reducing quality of trees in the future. Partially cut plots became well stocked with conifer regeneration, mostly western hemlock.

Keywords: Thinning, rotation age, western hemlock, *Tsuga heterophylla*, Sitka spruce, *Picea sitchensis*.

Farr, Wilbur A., and A. S. Harris.
1971. Partial cutting of western hemlock and Sitka spruce in southeast Alaska. USDA Forest Serv. Res. Pap. PNW-124, 10 p., illus. Pacific Northwest Forest & Range Experiment Station, Portland, Oregon.

Crop trees left after partial cutting were able to increase or maintain about the same rate of diameter growth as before thinning. but growth in diameter of trees in an unthinned stand followed the normal pattern of decline.

Opening the stand stimulated epicormic branching, thus reducing quality of trees in the future. Partially cut plots became well stocked with conifer regeneration, mostly western hemlock.

Keywords: Thinning, rotation age, western hemlock, *Tsuga heterophylla*, Sitka spruce, *Picea sitchensis*.

Farr, Wilbur A., and A. S. Harris.
1971. Partial cutting of western hemlock and Sitka spruce in southeast Alaska. USDA Forest Serv. Res. Pap. PNW-124, 10 p., illus. Pacific Northwest Forest & Range Experiment Station, Portland, Oregon.

Crop trees left after partial cutting were able to increase or maintain about the same rate of diameter growth as before thinning, but growth in diameter of trees in an unthinned stand followed the normal pattern of decline.

Opening the stand stimulated epicormic branching, thus reducing quality of trees in the future. Partially cut plots became well stocked with conifer regeneration, mostly western hemlock.

Keywords: Thinning, rotation age, western hemlock, *Tsuga heterophylla*, Sitka spruce, *Picea sitchensis*.

The mission of the PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION is to provide the knowledge, technology, and alternatives for present and future protection, management, and use of forest, range, and related environments.

Within this overall mission, the Station conducts and stimulates research to facilitate and to accelerate progress toward the following goals:

1. Providing safe and efficient technology for inventory, protection, and use of resources.
2. Development and evaluation of alternative methods and levels of resource management.
3. Achievement of optimum sustained resource productivity consistent with maintaining a high quality forest environment.

The area of research encompasses Oregon, Washington, Alaska, and, in some cases, California, Hawaii, the Western States, and the Nation. Results of the research will be made available promptly. Project headquarters are at:

College, Alaska	Portland, Oregon
Juneau, Alaska	Roseburg, Oregon
Bend, Oregon	Olympia, Washington
Corvallis, Oregon	Seattle, Washington
La Grande, Oregon	Wenatchee, Washington

The FOREST SERVICE of the U.S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.